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Different forage sources for F1 Holstein × Gir dairy cows ☆

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ABSTRACT

We evaluated the effect of four different forage sources on the performance of crossbred dairy cows under tropical conditions. The experiment was carried out on the Experimental Farm of the Agricultural Research Company of Minas Gerais, in Felixlândia-MG, Brazil. Twelve crossbred F1 Holstein × Gir cows were allocated to a triplicated 4 × 4 Latin square, balanced for residual effect, with each diet assigned to one group of three cows each period. The experiment had four treatments and five experimental periods of 21 days, with 14 days for adaptation and 7 days for data collection. The treatments included sorghum silage, corn silage, fresh sugarcane and sugarcane silage treated with 1% calcium oxide. Three markers LIPE®, titanium dioxide and iADF were used to estimate the individual intake and the apparent digestibility of the feed for the cows in each group. The data were subjected to analysis of variance and compared by a Tukey's test at 5% probability using the PROC GLM of SAS, version 8.0 for Windows software. The dry matter intake (DMI) and organic matter intake (OMI) were highest ($P<0.05$) for cows consuming corn silage ($P<0.05$) than for cows consuming sorghum silage, fresh sugarcane and sugarcane silage. The DMI for fresh sugarcane was lower than for corn silage and sorghum silage ($P<0.05$). DMI was least when cows were fed sugarcane silage ($P<0.05$). The dry matter digestibility (DMd) and organic matter digestibility (OMd) of corn silage, sorghum silage and fresh sugarcane were similar ($P>0.05$) but all were higher than for the sugarcane silage-based diet ($P<0.05$). Milk yield by cows fed corn silage and sorghum silage was similar ($P>0.05$) but both were higher than for cows fed sugarcane silage and fresh sugarcane. Non-esterified fatty acids in the plasma were the greatest ($P<0.05$) for cows fed sugarcane silage. Nitrogen balance was the greatest for cows fed corn and sorghum silage, followed by fresh sugarcane and then sugarcane silage ($P<0.05$). The sugarcane silage-based diet resulted in low intake, low digestibility, low efficiency of nitrogen utilization, and high mobilization of body reserves by F1 Holstein × Gir cows, but supported a milk production similar to cows fed fresh sugarcane. Corn silage and sorghum silage resulted in satisfactory cow performance and nitrogen utilization, even when the forage:concentrate ratio was high.

1. Introduction

The Gir, a breed of Indian origin, represents one of the zebu breeds used most commonly in tropical countries for animal production. The product of crossing Gir cattle with other cattle, such as Holsteins, introduces heterosis and ideal characteristics for milk production in warm climates. The F1 Holstein × Gir cows are adapted for milk production in tropical climates and grazing environments due their rusticity, high fertility, longevity, maternal ability and resistance to ectoparasites. Because pastures vary in chemical composition, nutritive value and availability throughout the year, supplemental forages

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during the winter are warranted because rain and daylight are insufficient.

Among the alternatives for supplementary feeding in times of pasture shortages, corn and sorghum are the species most commonly fermented for silage because of their ease of cultivation, high yields and high silage quality. Corn silage is the forage used most commonly in dairy cow diets in many countries. However, in tropical and subtropical areas, corn is less productive than sugarcane (Harris et al., 1983). In Brazil, sugarcane productivity can reach 81.3 t/ha, whereas that of corn can only reach 50 t/ha (Conab, 2009).

The main benefits of sugarcane as a fiber source for dairy cattle are its low cost per unit of dry matter yield, a maturity that coincides with the period of scarcity of pasture, and high productivity. However, fresh sugarcane must be cut daily, this is an operational limitation. Ensiling sugarcane would be an alternative method of preserving the dry matter content and nutritional quality of the forage. Using an additive may also help to minimize the production of alcohol that normally occurs in untreated silage due to the high soluble carbohydrate levels. The objective of this study was to evaluate the effect of various different forage sources on the performance of crossbred F1 Holstein × Gir dairy cows under tropical conditions.

2. Materials and methods

2.1. Location

The experiment was conducted on the Experimental Farm of the Agricultural Research Company of Minas Gerais, in Felixlândia-MG, Brazil. Laboratory analyses were at the Ruminant Nutrition Laboratory of the Animal Science Department at the Federal University of Viçosa (UFV) in Viçosa, MG, Brazil. Animal care and handling procedures followed the guidelines of the Federal University of Viçosa.

2.2. Animals, diets, experimental design and management

Twelve crossbred F1 Holstein × Gir cows were allocated to a 4 × 4 extra-period Latin square, balanced for residual effects (Lucas, 1957); each experimental treatment was assigned to one group of three cows. The experiment consisted of four treatments over five experimental periods of 21 days, with 14 days of adaptation and 7 days of data collection. The last period was a repetition of the fourth period, used to estimate residual effects of forage among periods.

The treatments consisted of diets of sorghum silage (SS), corn silage (CS), fresh sugarcane (FSC) and sugarcane silage treated with 1% calcium oxide (SCS). The SP80-1816 variety of sugarcane was ensiled with 19 °Brix. The diets were formulated to be isonitrogenous (14% CP), with urea used to match the CP content between forages because the same concentrate was used for all diets (Table 1). Diets were formulated according to the recommendations of the NRC (2001) to meet the nutritional requirements of cows weighing 500 kg and producing 15 kg of milk daily for 110 days, with milk containing 4.0% fat and 3.2% protein. Cows were allocated to diets while in the feedlot, in groups of three. Each group received their diet twice a day at 7:30 a.m. and 3:00 p.m. The daily amount of provided feed and the orts from each treatment were weighed to estimate feed intake.

Table 1
Ingredients composition of the concentrate (% of the DM).

Ingredients	Diet			
	SCS[a]	SS[b]	CS[c]	FSC[d]
Urea/ammonium sulfate (9:1)	6.42	3.91	3.16	6.68
Soybean meal	26.21	26.90	27.12	26.12
Corn meal	64.20	65.92	66.42	64.01
Mineral mix[e]	3.18	3.26	3.29	3.18

Dicalcium phosphate (43.4%); sodium chloride (7.5%); Cobalt sulfate (1.49%), Copper sulfate (4.51%), Zinc sulfate (12.0%), Potassium iodide (0.60%), Sodium selenite (0.30%).
[a] Sugarcane silage.
[b] Sorghum silage.
[c] Corn silage.
[d] Fresh sugarcane.
[e] Limestone (30.2%).

2.3. Intake estimation

The three markers (LIPE®, titanium dioxide and indigestible acid detergent fiber — iADF) method was used to estimate intake by individual cows in each group and apparent digestibility of the feed for the cows in each group (Valadares Filho and Marcondes, 2009). LIPE® (lignin isolated, purified and enriched from *Eucalyptus grandis*) was used to estimate the excretion of fecal matter (as dry weight). From the twelfth until the seventeenth day of each experimental period, a 500 mg capsule of this marker was provided as a pulse dose during the morning milking, in the milk parlor, using individual concentrate bin for each cow. The marker was fed for a total of 6 days; the first 3 days were to stabilize the fecal excretion of the marker, with fecal sampling on the last 3 days. Fecal samples were collected twice a day after each milking (Saliba, 2005).

The fecal samples were dried, ground and composed proportionately on each of 3 days of sampling, within each animal, based on fecal dry weights. Approximately 10 g of each composed sample of feces was sent to the Federal University of Minas Gerais to estimate the total daily fecal output by two methods of LIPE® measurement as described by Saliba (2005).

One kilogram of concentrate was provided for the first 8 kg of milk produced, with one additional kg of concentrate provided for every 3 kg additional of milk produced. The animals received equal amounts of concentrate in the collective bin at the feedlot, and differences in concentrate intake inherent to each cow were corrected through individual supplementation in the bin at the parlor. The concentrate supplied and the orts were weighed for each cow. Titanium dioxide was used to estimate the individual intake of concentrate in the collective bin at the feedlot (Valadares Filho and Marcondes, 2009). From the seventh until the seventeenth day, the cows were supplied with 15 g of this marker that was completely mixed into the concentrate using a mixer. Thus, 45 g of marker was used per day for each group of three cows. The marker was given for a total of 11 days: 6 days to stabilize fecal excretion of the marker, and 5 days to sample the feces twice a day after milking.

Fecal samples were dried (65 °C), ground and composited proportionately (dry basis) for each of the three days of sampling, for each animal. The concentration of titanium

dioxide was determined using techniques described by Myers et al. (2004). The concentrate intakes from the collective bin at the feedlot were estimated by dividing the total fecal excretion of titanium dioxide by the concentration of titanium dioxide in the concentrate. The resulting value was added to the concentrate intake of each cow's individual bins at the milking parlor.

The individual intakes of forage were estimated using the internal marker iADF. Individual forage intakes were estimated by subtracting marker excretion from the concentrate from the total iADF excretion and dividing that difference by the concentration of the marker in the forage. The samples of feces, forages and concentrate were placed in Ankon bags (Filter bag F57) and incubated in the rumen of a fistulated crossbred animal for a period of 11 days (Casali et al., 2008). When the bags were withdrawn from the rumen, they were soaked in water for 30 min and gently washed by hand under running water until the wash water ran clear. The bags were then placed in an ANKOM 200 fiber Analyzer, as described by Ferreira and Mertens (2007), and the iADF was determined by weighing the bags with a digital scale after drying them in an oven, first at 60 °C for 72 h followed by 105 °C for 8 h. The residue was considered the iADF.

2.4. Milking procedures

The cows were milked at 0700 and 1400 h. Daily milk yield was recorded. The milk was sampled in proportion to the milk produced on the sixteenth day of the trial period. The samples were placed in plastic bottles with bronopol® and sent to the Laboratory of Milk Quality, UFMG-Brazil, to determine the fat, protein, lactose and total solid contents using methods described by the IDF (1996). Fat-corrected milk (4%FCM) was calculated according to the NRC (2001). Another part of the composited sample of milk was deproteinized with trichloroacetic acid (10 mL of milk mixed with 5 mL of 25% trichloroacetic acid) and filtered through a paper filter. The filtrate was stored at 20 °C for later analysis of the urea and allantoin contents.

2.5. Sampling and analytical procedures

During the experimental period, diets were sampled daily and frozen shortly thereafter. At the end of each week, a composed forage sample was prepared and dried. At the end of each period, another composited sample was prepared based on the dry weight of each weekly sample in the 21 day period. All samples were dried in a ventilated oven at 60 °C for 72 h and ground through a 2-mm screen. The samples were stored in a plastic container for further analysis. The dry matter (DM), organic matter (OM), ash and crude protein (CP) were analyzed as described in the AOAC (2000) methods. The ether extract (EE) was obtained by Soxhlet extraction with petroleum ether. The concentrations of acid detergent fiber (ADF) and neutral detergent fiber without sodium sulfite (NDF), as well as NDF corrected for ash and protein (apNDF), were determined following the protocols suggested by Mertens (2002) and were analyzed with heat-stable α-amylase (Ankon Tech. Corp., Fairport, NY). Lignin was extracted with 72% sulfuric acid (Van Soest and Wine, 1967). Non-protein nitrogen (NPN) was analyzed according to the procedure of Licitra et al. (1996). Neutral detergent insoluble nitrogen (NDIN) was quantified using the Kjeldahl nitrogen method (Licitra et al., 1996). Table 2 shows the composition of the ingredients used in the experimental diets. The total nitrogen in the feces and urine was determined using the Kjeldahl nitrogen method, while milk nitrogen was calculated by dividing the milk protein (IDF, 1996) by 6.25.

On the fourteenth day of the adaptation period, and at the end of each experimental period, the cows were weighed immediately after milking and changes in body weight were calculated. Blood samples were collected on the 21st day by coccygeal venipuncture using tubes coated with the anticoagulant EDTA, tubes were centrifuged immediately at 2800 $\times g$ for 15 min. Plasma was recovered, packed in plastic containers and frozen at −15 °C until analyzed for non-esterified fatty acids (NEFA) and urea nitrogen. For NEFA determination, a commercial kit was used (Wako Diagnostics, Richmond, VA, USA) by adapting the reagent optimization technique (Johnson and Peters, 1993).

Urine spot samples were collected on day 21 of each period, immediately after milking, with a stimulating massage. After the homogenization and filtration, 10 mL aliquots of urine were taken and diluted to 40 mL with 0.036 N sulfuric acid, as described by Valadares et al. (1997). These samples were adjusted to a pH of 3.0 to avoid bacterial destruction of purine derivatives. Then the samples were placed in plastic bottles, properly identified and frozen for later analysis of urea, total nitrogen, creatinine, uric acid and allantoin. The total daily urine volume was estimated by dividing the estimated of daily urinary excretion of creatinine by the observed values of creatinine concentration in the

Table 2
Chemical composition of the ingredients used in experimental diets (% of the DM).

Components	SCS[a]	SS[b]	CS[c]	FSC[d]	Concentrate
Dry matter	25.23	30.72	31.01	29.18	87.30
Organic matter	92.70	95.18	96.31	97.98	93.89
apNDF	53.56	59.34	51.91	44.25	10.33
iNDF	30.80	44.42	34.13	29.49	1.89
apADF	32.88	34.94	29.04	25.80	2.64
iADF	21.61	15.72	11.52	17.41	0.80
Lignin (%DM)	7.94	7.07	4.43	6.17	1.75
Lignin (%ADF)	24.14	20.23	15.25	23.91	–
Indigestible fraction	35.57	28.59	20.48	33.46	–
pdNDF factor	2.07	3.72	3.99	1.79	–
Crude protein	3.51	4.99	6.03	2.67	21.62
NPN (% N)	49.78	63.08	53.40	77.00	20.12
NDIN (%FDN)	3.14	2.82	3.21	1.87	19.00
Ether extract	1.74	1.55	2.15	1.70	2.00
NFC	31.69	27.36	33.51	47.22	57.44

apNDF = neutral detergent fiber corrected for ash and protein; iNDF = indigestible neutral detergent fiber; apADF = acid detergent fiber corrected for ash and protein; iADF = indigestible acid detergent fiber; NPN = non-protein nitrogen; NDIN = neutral detergent insoluble nitrogen; NFC = non-fiber carbohydrates; % Indigestible fraction = (lignin*2.4)/NDF by Van Amburgh et al. (2003); pdNDF factor = iNDF/(Lignin/NDF) by Raffrenato and Van Amburgh (2010).

[a] Sugarcane silage.
[b] Sorghum silage.
[c] Corn silage.
[d] Fresh sugarcane.

urine according to Valadares Filho and Valadares (2001). The daily urinary creatinine excretion was estimated by using 24.05 mg of creatinine per kg of unshrunk body weight of dairy cows, and the assumption that creatinine is excreted constantly over 24 h (Chizzotti et al., 2007).

Allantoin, uric acid and creatinine in the urine were measured by high-performance liquid chromatography (HPLC) according to the protocol described by George et al. (2006). The allantoin in the milk serum was analyzed by the colorimetric method of Chen and Gomes (1992). Urea in the plasma and milk serum was determined using commercial kits for analysis (Labtest Diagnóstica, Uréia CE, Lagoa Santa, Minas Gerais).

2.6. In situ degradation kinetics

The dry matter degradation coefficients for the forages, a, b and kd, were calculated from the following equation: DM degradation = a + b $(1-\exp^{-KdT})$, where a = the soluble fraction, b = the insoluble and potentially degradable fraction and kd = the degradation rate of fraction b at time t. The passage rate (kp) was calculated according to the NRC methodology (2001), using the following equations for fresh forage and silages: kp = 3.054 + 0.614 × DMI, in which the dry matter intake is expressed as unshrunk body weight percentage of (%BW).

The NDF degradation kinetics in the rumen for forages were analyzed using in situ incubations for 0, 2, 4, 8, 16, 24, 48, 72, 96 and 240 h, parameters were estimated using the model presented by Mertens and Loften (1980) and described by the function $Yt = b * \exp^{(-kd\ (t-L))} + I$, where Yt = the undegradable residue at time t (%); b = the potentially degradable fraction of NDF (%); Kd = the degradation rate of b (h^{-1}), t = an independent variable referring to the time (h); L = the discrete lag (h); I = the undegradable NDF fraction. The effective rumen degradation (ED) was calculated by the model ED = b * [kd/(kd + kp)], where kp = the feed passage rate through the rumen (h^{-1}).

2.7. Calculation and statistical analyses

The non-fiber carbohydrates were corrected for ash and protein (NFCap) as proposed by Hall (2001) as follows: NFCap = 100 − [(%CP − %urea CP + %urea) + NDFap + %EE + % ash]. The total digestible nutrients (TDN) were calculated according to Weiss (1999) by the following equation: TDN (%) = dCP + dNDF + 2.25dEE + dNFC, where dCP = the digested crude protein; dNDF = the digested neutral detergent fiber; dNFC = the digested non-fiber carbohydrates; dEE = the digested ether extract.

Nitrogen balance was calculated as the difference between total nitrogen intake and total nitrogen excreted in the feces and urine as well as secreted in the milk. The total excretion of purine derivatives (PD) was calculated as the sum of the allantoin and uric acid excreted in the urine and the allantoin secreted in the milk. The absorbed purines (X mmol/day) were calculated from the PD excretion (Y, mmol/day) using the equation $Y = 0.85 + 0.385PV^{0.75}$, where 0.85 is the recovery of absorbed purines as purine derivatives and $0.385PV^{0.75}$ is the endogenous contribution to purine excretion (Verbic et al., 1990). Microbial protein synthesis in the rumen (Y, gN/day) was calculated based on the absorbed purines (X, mmol/day) using the equation Y = (70X)/(0.83 × 0.116 × 1000), where 70 represents the N content in purines (mg N/mmol), 0.83 is the microbial purine digestibility and 0.116 is the ratio between purine-N and the bacterial-N (Chen and Gomes, 1992).

The data were subjected to analysis of variance according to the model:

$$Y_{ijkl} = \mu + D_i + R_i + A_j + P_k + e_{ijk} + \varepsilon_{(ijk)l}$$

where: μ = general constant; D_i = direct effect of treatment i; R_i = residual effect of treatment i; A_j = effect of the animal j; P_k = effect of the experimental period k; e_{ijk} = random error among experimental plots; and $\varepsilon_{(ijk)l}$ = random error within experimental plots.

The analysis of variance was performed using the PROC GLM of SAS 9.1. The residual effects of treatments were estimated using the CARRY statement. Additionally, the error among experimental plots was calculated using the LACKOFIT option and it was used to test the direct and residual effects of treatments. It must be emphasized that residual effects of treatments were found to be not significant for any variable. So, they were not presented and discussed. When necessary, direct effects of treatments were compared using Tukey's test. All statistical procedures were performed adopting α = 0.05.

3. Results

3.1. Dry matter intake

The nutrient composition of the forages fed to cows is shown in Table 2, and the DMI is shown in Table 3. Sorghum silage contained higher NDF, iNDF and lignin contents than

Table 3
Average daily intakes of nutrients by F1 crossbred Holstein × Gir cows fed different forage sources.

	Forages				SEM[5]	P-value
	SCS[1]	SS[2]	CS[3]	FSG[4]		
Intakes (kg/day)						
Total dry matter	7.54[d]	12.73[b]	14.58[a]	10.38[c]	0.14	<0.001
Forage dry matter	5.02[d]	10.03[b]	11.55[a]	7.71[c]	0.11	<0.001
Organic matter	7.02[d]	12.16[b]	14.09[a]	10.15[c]	0.14	<0.001
Crude protein	1.15[c]	1.54[b]	1.81[a]	1.43[b]	0.65	<0.001
Lipids	0.13[b]	0.21[b]	0.29[a]	0.18[b]	0.28	<0.001
Neutral detergent fiber	2.96[c]	6.21[a]	6.33[a]	3.67[b]	0.07	<0.001
Indigestible NDF	1.54[d]	4.51[a]	3.99[b]	2.12[c]	0.05	<0.001
Non-fiber carbohydrates	3.36[c]	4.83[b]	6.29[a]	5.86[ab]	4.03	<0.001
Total digestible nutrients	4.77[c]	8.45[b]	10.79[a]	7.64[b]	6.16	<0.001
Intakes (% BW)						
Total dry matter	1.48[d]	2.43[b]	2.85[a]	2.08[c]	0.03	<0.001
Neutral detergent fiber	0.58[c]	1.19[a]	1.23[a]	0.73[b]	0.01	<0.001

[a,b,c] Different superscripts at the same row indicate a significance difference mean between diets at the 0.05 level.
[1] Sugarcane silage.
[2] Sorghum silage.
[3] Corn silage.
[4] Fresh sugarcane.
[5] Standard error of means among the different groups.

did the corn silage. Sugarcane silage had higher levels of NDF, CP and NDIN and lower levels of NPN and NFC than did fresh sugarcane. Despite its lower NDF and ADF contents, fresh sugarcane had a higher iADF content and a higher lignin content (in terms of %ADF) than did the other diets. The dry matter intake (DMI) (kg and %BW) and organic matter intake (OMI) were highest ($P<0.05$) for cows consuming CS>SS>FSC>SCS. Note that the sorghum silage contained higher NDF, iNDF and lignin than corn silage. The DMI of fresh sugarcane was lower than that of corn silage and sorghum silage ($P<0.05$). Despite its lower NDF and ADF contents, fresh sugarcane had a higher iADF and a higher lignin as a fraction of ADF than the other diets. DMI was lowest for cows fed sugarcane silage ($P<0.05$). Sugarcane silage had higher levels of NDF, CP and NDIN and lower levels of NPN and NFC than fresh sugarcane.

3.2. Nutrient intake

The nutrient intake of cows fed different forage sources is presented in Table 3. Crude protein intake (CPI) for the corn silage-based diet was higher ($P<0.05$), than for diets based on sorghum silage and fresh sugarcane, that had similar CPI. Sugarcane silage resulted in lower protein intake than the other treatments. Ether extract (EE) intake was higher for cows fed corn silage ($P<0.05$) than for cows fed other forages that did not differ in EE intake.

Neutral detergent fiber intake (NDFI) (kg and %BW) was similar for cows receiving corn and sorghum silages, both being higher than that for cows given fresh sugarcane ($P<0.05$). The sugarcane silage diet had the lowest NDFI.

Non-fiber carbohydrate intake (NFCI) for corn silage and fresh sugarcane was higher than that for sugarcane silage ($P<0.05$). However, NFCI for fresh sugarcane did not differ from that for sorghum silage. Sugarcane silage resulted in the lowest NFCI.

Total digestible nutrient intake (TDNI) from corn silage was highest ($P<0.05$), followed by sorghum silage and fresh sugarcane, which had similar TDNI. Sugarcane silage provided the lowest TDNI.

3.3. Digestibilities

The digestibilities of the diet fed to cows are presented in Table 4. The dry matter digestibility (DMd) and organic matter digestibility (OMd) of corn silage, sorghum silage and fresh sugarcane were equal, but higher than those of the sugarcane silage-based diet ($P<0.05$). There were differences ($P<0.05$) in the crude protein digestibility (CPd) between diets based on corn silage and sugarcane silage, but the CPd for diets based on sorghum silage and fresh sugarcane was not different from the CPd for other treatments. There was no significant difference in the ether extract digestibility (EEd) among the different diets.

Neutral detergent fiber digestibility (NDFd) differed ($P<0.05$) between the corn silage-based and sugarcane silage-based diets. The sorghum silage and fresh sugarcane diets were similar in NDFd. The non-fiber carbohydrate digestibility (NFCd) was higher for the fresh sugarcane and corn silage diets ($P<0.05$), and there was no difference in the NFCd between the sugarcane silage and sorghum silage diets.

Total digestible nutrients (TDN) were similar for corn silage, sorghum silage and fresh sugarcane diets. Sugarcane silage diet had the lowest TDN content, although this diet was not lower than for the sorghum silage.

Table 4
Average digestibilities of the nutrients by F1 crossbred Holstein × Gir cows fed different forage sources.

Coefficients of digestibity (%)	Forages				SEM[5]	P-value
	SCS[1]	SS[2]	CS[3]	FSC[4]		
Dry matter	50.28[b]	61.31[a]	65.86[a]	59.98[a]	0.66	<0.001
Organic matter	54.25[b]	63.42[a]	67.95[a]	62.84[a]	0.66	0.0071
Crude protein	66.37[b]	69.21[ab]	69.86[a]	68.35[ab]	0.40	<0.001
Lipids	66.99	68.62	80.49	71.65	1.97	0.0134
Neutral detergent fiber	29.82[c]	50.97[ab]	56.92[a]	33.57[bc]	1.87	<0.001
Non-fiber carbohydrates	79.11b[c]	78.59[c]	81.72[ab]	86.17[a]	0.54	0.0034
Total digestible nutrients	60.07[b]	67.53[ab]	71.63[a]	70.02[a]	0.92	<0.001

[a,b,c] Different superscripts at the same row indicate a significance difference mean between diets at the 0.05 level.
[1] Sugarcane silage.
[2] Sorghum silage.
[3] Corn silage.
[4] Fresh sugarcane.
[5] Standard error of means among the different groups.

3.4. Milk parameters

Milk yields from cows fed corn silage and sorghum silage diets were similar but higher than the milk yields from cows fed sugarcane silage and fresh sugarcane diets, which were both similar (Table 5). There was no difference in composition of milk among the experimental diets.

3.5. In situ degradation kinetics

Fresh sugarcane had the highest DM soluble fraction (a), but its potentially degraded fraction (b) and the disappearance rate for DM (kd) were lower than for the other forages. Fresh sugarcane also had a larger undegraded fraction of the NDF (I)

Table 5
Average milk yield and milk composition by F1 crossbred Holstein × Gir cows fed different forage sources.

Parameters	Forages				SEM[5]	P-value
	SCS[1]	SS[2]	CS[3]	FSC[4]		
FCM4% (kg/day)	9.96[b]	12.54[a]	13.76[a]	11.13[b]	0.12	0.0012
Fat%	4.14	4.09	4.27	4.11	0.06	0.9470
Protein%	3.06	3.06	3.34	3.22	0.03	0.1853
Lactose%	4.58	4.60	4.49	4.54	0.01	0.1358
Total solids%	12.67	12.64	13.17	12.83	0.11	0.7741
Solids non-fat%	8.53	8.54	8.89	8.71	0.05	0.0908
Body weight change[**] (kg/day)	−1.07	0.444	0.126	−0.515	–	–

[a,b,c] Different superscripts at the same row indicate a significance difference mean between diets at the 0.05 level.
[1] Sugarcane silage.
[2] Sorghum silage.
[3] Corn silage.
[4] Fresh sugarcane.
[5] Standard error of means among the different groups.
** Not statistically evaluated. This variable does not follow the continuous probability distribution.

Table 6
Characterization of the kinetic parameters of the in situ ruminal DM and NDF degradation of the different forage sources.

	Forages			
	SCS[a]	SS[b]	CS[c]	FSC[d]
DM				
a%	34.13	23.37	33.17	53.43
b%	37.54	52.10	46.65	21.67
Kd. h^{-1}	1.47	1.68	2.21	1.24
ED%	47.57	37.44	43.23	58.65
A-SD	9.14	6.85	8.85	1.93
NDF				
B%	45.85	56.18	51.11	34.66
I%	37.94	30.58	31.92	50.54
Kd. h^{-1}	1.70	1.81	2.76	1.78
ED%	13.77	16.01	17.41	10.86
A-SD	5.71	5.16	4.96	2.43

a% — soluble fraction; b% or B% — potentially degradable fraction; I — Undegradable fraction; kd% — degradation rate of the b% fraction; ED% — Ruminal effective degradability; A-SD — Asymptotic standard-deviation.
[a] Sugarcane silage.
[b] Sorghum silage.
[c] Corn silage.
[d] Fresh sugarcane.

and lower effective degradability of the NDF. In contrast, sorghum silage (Table 6) had the smallest soluble fraction (a) and a higher potentially degraded fraction than the other forages (b). Sugarcane silage had a disappearance rate (kd) for DM lower than for corn and sorghum silages and an even lower disappearance rate of NDF. Corn silage had the highest disappearance rate (kd) for DM and NDF and the highest effective degradation of NDF.

3.6. Metabolic parameters

The metabolic parameters of cows fed different forage sources are presented in Table 7. Cows fed sugarcane silage had higher non-esterified fatty acid (NEFA) contents in their plasma than cows fed other silages ($P<0.05$). Nitrogen balance was the greatest ($P<0.05$) for cows fed corn and sorghum silage, followed by fresh sugarcane and sugarcane silage. There was no difference in the nitrogen content in the urine, probably due to the high variation. Milk nitrogen was highest for cows consuming corn silage ($P<0.05$). There were no differences among the other treatments for this parameter. The urine urea nitrogen (UUN), plasma urea nitrogen (PUN) and milk urea nitrogen (MUN) were highest ($P<0.05$) for cows fed sugarcane silage. Cows consuming corn silage had the lowest PUN, MUN and UUN ($P<0.05$). Among the treatments, corn silage promoted the highest production of total excreted purines and microbial nitrogen in the rumen. In contrast, the microbial efficiency of the corn silage based diet was similar to those fed SS and FSC.

4. Discussion

4.1. Dry matter intake

The high level of iNDF consumption by cows fed sorghum silage may have limited dry matter intake, in contrast to corn silage. Van Soest (1994) reported that the DMd, and therefore the OMd, depends on the cell wall content and its availability for digestion, as determined by the lignification degree and other factors. When lignin content increases, the correlation between intake and digestibility increases as well.

To determine the undegradable fraction of feedstuff, Van Amburgh et al. (2003) described a mathematical approach for calculating the rates of digestion for a fixed iNDF pool. The indigestible fraction was estimated using the formula (ADL × 2.4)/NDF. Following this concept, sorghum silage had a higher indigestible fraction (28.59%) than corn silage (20.48%). This mathematical approach also is supported by the iNDF intake (iNDFI) for these two forages, being 4.51 kg for sorghum silage and 3.99 kg for corn silage (Table 3), despite the NDFI being the same. The iNDFI represented 35.49% of the diet for sorghum silage and 27.36% for corn

Table 7
Averages of the metabolic parameters of F1 crossbred Holstein × Gir cows fed different forage sources.

Item	Forages				SEM[5]	P-value
	SCS[1]	SS[2]	CS[3]	FSC[4]		
Non-esterified fatty acids (mM)	393.37[a]	175.02[b]	122.51[b]	178.54[b]	0.52	<0.001
Ingested nitrogen (g)	183.50[c]	247.84[b]	289.34[a]	229.61[b]	3.27	<0.001
Fecal nitrogen (g)	60.75[c]	76.21[ab]	87.40[a]	71.49[bc]	1.46	<0.001
Urine nitrogen (g)	120.66	81.79	90.91	119.31	5.39	0.6077
Milk nitrogen (g)	46.84[b]	61.67[b]	70.62[a]	56.45[b]	0.52	0.0117
Nitrogen balance (g)	−44.75[b]	28.16[a]	40.39[a]	−17.64[b]	7.36	0.0043
Nitrogen balance (% of the ingested)	−25.99[b]	11.18[a]	13.96[a]	−10.28[b]	3.97	0.0357
Urine urea nitrogen (mg/kg BW)	281.58[a]	193.78[ab]	153.88[b]	240.38[ab]	10.32	0.0120
Plasma urea nitrogen (mg/dl)	19.64[a]	13.93[b]	11.27[c]	15.65[b]	0.25	<0.001
Milk urea nitrogen (mg/dl)	21.84[a]	15.49[b]	12.53[c]	17.40[b]	0.28	<0.001
Urine total purines (mM)	236.98[b]	232.92[b]	302.23[a]	248.25[b]	4.58	0.0101
Ruminal microbial nitrogen (g)	134.75[b]	131.32[b]	182.74[a]	143.51[b]	3.34	0.0128
Microbial efficiency (gCP/kgTDN)	189.45[a]	101.64[b]	114.85[b]	127.51[b]	7.32	0.0318
Allantoin: uric acid ratio (%)	81.77	78.85	80.81	81.33	0.83	0.8160

[a,b,c] Different superscripts at the same row indicate a significance difference mean between diets at the 0.05 level.
[1] Sugarcane silage.
[2] Sorghum silage.
[3] Corn silage.
[4] Fresh sugarcane.
[5] Standard error of means among the different groups.

silage. The iNDFI may explain the higher intake of corn silage than sorghum silage. Adding to these factors, Raffrenato and Van Amburgh (2010) have stated that both lignin and iNDF after 240 h of fermentation can have a dynamic relationship. Thus, forage group-specific values, according to the lignin: NDF ratio of the specific forage, can be used to predict the potentially degradable NDF (pdNDF). The ratio iNDF/(Lignin/NDF) can be used to calculate the pdNDF of each forage, such as corn silage and sorghum silage. These two forages presented pdNDF values of 3.99 and 3.72, respectively, and this indicates that corn silage was more extensively degraded than sorghum silage (Table 1).

Dann et al. (2008) compared different varieties of sorghum silage to corn silage. They observed lower intakes of dry matter and organic matter for animals fed sorghum silage and also found lower levels of starch in some sorghum cultivars. A similar trend is apparent in our study, as the lowest level of non-fiber carbohydrates was for sorghum silage (Table 2).

Despite its lower fiber content, the low quality of the fresh sugarcane fiber had negative effects on the dry matter and organic matter intakes. Consumption of forages is limited by the rate of removal of particles from the rumen–reticulum. This removal rate is linked to the chemical composition of the forage, its particle size, the digestion rate of the digestible content, and the clearance of indigestible fill (McDonald et al., 1991). Thus, the high iADF content in sugarcane, especially when compared with corn silage, appears to have limited intake. Sugarcane also had a lower pdNDF factor (2.07) and a higher indigestible fraction (22.35%) compared to corn and sorghum silage (Table 1). The fiber digestion rate of sugarcane is low, and the accumulation of undigested fiber in the rumen limits intake (Valadares Filho et al., 2008). The soluble sugars in sugarcane account for most of the energy the animal gets from this forage. However, while the sugars are rapidly fermented in the rumen, structural carbohydrates are utilized slowly (Landell et al., 2002).

The decreased NPN and NFC contents of sugarcane silage and its high concentration of NDF were consequences of the soluble carbohydrate fermentation and volatilization losses, resulting in high amounts of cell wall components. Especially for sugarcane silage, Kung and Stanley (1982) reported that an abundance of soluble substrates for fermentation, especially sucrose, promotes rapid hydrolysis to glucose and fructose monomers during fermentation; yeast microflora are responsible for converting sugars to alcohol. Van Soest (1994) reported that silage intake can often be less than expected for non-fermented forages with similar NDF content, probably a result of the negative metabolic balance induced by fermentation losses. McDonald et al. (1991) stated that silage DMI by ruminants is regulated by similar mechanisms as fresh forage. However, DM intake often is lower for silage than for fresh forage or hay.

Costa et al. (2005) evaluated different replacement levels of corn silage with fresh sugarcane for Holstein cows fed 60% dietary forage. They observed an 18% reduction in the DMI for cows fed sugarcane, but intake was similar to that of corn silage when the forage proportion was reduced to 40%. Magalhães et al. (2004) found a 30 g decrease in the DMI of fresh sugarcane for each percentage unit of corn silage replaced, reaching a 13.8% decrease in intake when sugarcane replaced 100% corn silage. In our study, the fresh sugarcane DMI was 74.2% of the diet, and a 28% decrease in intake was observed. It should be emphasized that we have supplemented concentrate according to milk production. This practice results in reduction in concentrate supplementation as the cows reduces their milk production. This can result in a high reduction in intake when cows fed low quality forages such as sugarcane. In turn this can promote a high reduction in milk production. However, this is a common and feasible practice in the Brazilian dairy farms.

Reports of the performance of dairy cows consuming sugarcane silage are even scarcer. Neves Neto (2009) worked with pure Holstein cows or cows crossed with Jersey that were fed diets of 55% sugarcane silage. They observed an average DMI of 16.07 kg and milk production of 16.03 kg/day, but the cows were treated with BST, so it was not possible attribute this performance solely to the diet. Valvasori et al. (1998) fed cottonseeds to cows; they found no difference in intake when sorghum silage was fully replaced with sugarcane silage, achieving an average intake of 14.14 kg/day. However, milk production decreased by 9%.

4.2. Nutrient intake

In this experiment, the CPI followed the DMI of the diets. This was expected because the diets were formulated to have similar crude protein contents. The only exception was that, although the DMI of the corn silage was greater than that of sorghum silage, CPI was not. This lack of an increase in the CPI may be due to increased variability in CPI, as is reflected by its higher coefficient of variation.

Dias et al. (2001) compared corn silage and sorghum silage for dairy cows and reported similar DMI and CPI. Nascimento et al. (2008) also observed similar DMI and CPI when comparing corn silage to saccharin sorghum silage. Other authors (Costa et al., 2005, Magalhães et al., 2004, Mendonça et al., 2004) evaluated different substitution levels of fresh sugarcane for corn silage. They also observed that the CPI followed the DMI. As the amount of fresh sugarcane in the diet increased, CPI values decreased.

Lipid intake was higher for cows fed corn silage than other forages. This was due to higher intake of corn silage compared to other forages and the higher amount of lipid present in corn silage (Table 2).

The NDFI paralleled the DMI, except for the sorghum silage NDFI, which was similar to the corn silage NDFI, despite a higher corn silage DMI. This fact probably was due to higher iNDFI of sorghum silage than corn silage (Table 3), that may have limited sorghum silage intake. In general, forage intake varies inversely with the rumen fill, which is affected by the forage fiber mass. This relationship explains the fact that there was a greater correlation between intake and NDF in the diet than any other nutrient. The NDF is the most suitable chemical predictor of the DMI (Allen, 1996; Van Soest, 1965, Waldo, 1986). In the present study, the NDFI was an immediate consequence of the DMI due the high correlation between these two variables in the diet. High correlations between DMI and CPI, as well as between DMI and NFCI ($r = 0.965$ and 0.939 respectively) were observed in this study. These correlations were slightly higher than correlations between DMI and apNDFI ($r = 0.897$). However, the

high forage:concentrate ratio used in this study maintains the NDF as a suitable chemical predictor of the DMI. Aydin et al. (1999) replaced corn silage with sorghum silages of different varieties for dairy cows. They observed DMI was higher for corn silage, but the NDF intakes were statistically equal, because NDF content of sorghum silage was higher.

The NFCI of corn, sorghum and sugarcane silages varied with the DMI ($r = 0.939$). DMI for fresh sugarcane did not present this pattern because of its high NFC content. Thus, the fresh sugarcane NFCI was similar to that of corn silage, even though the intake of corn silage was greater than that of other forage. Costa et al. (2005) replaced 100% of the corn silage in a diet with fresh sugarcane; their results were in agreement with this work. Because intake was greater for corn silage than for fresh sugarcane intake, no effects of NFC on DMI were found from these two feeds. NFCI was high for sugarcane, even though DMI was low, due to high NFC of fresh sugarcane.

TDNI was highest for corn silage due to high DMI. However, the TDN intakes from sorghum silage and fresh sugarcane were similar due to high intake of sorghum silage than fresh sugarcane. NRC (2001) reported that 50–100% of silage NFC consists of starch. The digestibility of starch from sorghum silage may be less than for other silages. In contrast, the sugarcane NFC is composed primarily of sucrose (Preston, 1977), which is highly soluble, resulting in an increase in TDNI. This was reflected by the greater NFC digestibility of the diet with fresh sugarcane in our study (Table 4).

4.3. Digestibility

Sugarcane silage had a high percentage of ADF and lignin (Table 2), this may explain the lower DMd and lower DMI. Van Soest (1994) reported that DMd and consequently, OMd, depend on the cell wall content and its availability for digestion. These digestibilities are determined by the lignification degree as well as other factors. When the lignin content increases, so does the relationship between intake and digestibility. In this work, the low NDF digestibility of the sugarcane silage-based diet provided a considerable reduction in DMd, probably due to high forage:concentrate ratio. Although DMd across diets was more closely related to CPd ($r = 0.864$) than to apNDF ($r = 0.746$).

The DMd and OMd of corn silage, sorghum silage and fresh sugarcane did not differ significantly; this could be a mechanism to compensate for carbohydrate digestion. Costa et al. (2005) found no difference in the DMd and OMd when corn silage was replaced with fresh sugarcane. However, these authors suggested that the low NDFd from sugarcane may have been offset by its high NFCd of this forage, as also was observed in our study. In the case of corn and sorghum silages, although sorghum silage is richer in NDF, iNDF and lignin content than corn silage, intake was less than for corn silage diet.

The CPd differences could be attributed to differences in endogenous protein loss from the gut. Nitrogen intake and the fecal nitrogen content were higher in corn, sorghum silage and fresh sugarcane than in sugarcane silage even though CP of the diet was higher for the sugarcane silage based diet (Table 7). Metabolic fecal N probably was greater for cows consuming sugarcane silage than other forages due to a greater percentage of NDF in feces, which promoted reduced apparent CPd (Table 4). Tamminga (1992) reported that fecal N loss results from excretion of undigested feed N, undigested microbial N, and endogenous N, the latter being increased when sloughing of epithelial cells of the gut wall increases.

The largest concentrate proportion was in the sugarcane silage-based diet (33.4%) when compared to diets containing sorghum and corn silage and fresh sugarcane (21.2, 20.8 and 25.7%, respectively). This higher proportion was a consequence of low forage intake (Table 3) and might explain the lower NDFd for this diet. Allen (1996) reported that the extent of fiber digestion is reduced by adding non-fiber carbohydrates to the concentrate that reduce ruminal pH. Varga et al. (1998) also indicated that passage rate and fiber digestion rate are affected by the non-structural carbohydrate content of the diet, because fibrolytic bacteria compete with amylolytic bacteria for the same nutrients.

The NFCd results agree with previous comments. Corn silage and fresh sugarcane provided the same NFCI, despite the lower DMI of fresh sugarcane. Similar digestibility can be attributed to the high NFC content of fresh sugarcane, basically sucrose, a highly soluble carbohydrate. In addition, sugarcane silage had an intermediate NFC digestibility because it is produced from fresh sugarcane. Fermentation losses reduced the soluble carbohydrate and thus the NFC would be less representative in comparison to the cell wall. Thus, the proportion between mobile content and cell wall probably decreased. Sorghum silage had the lowest NFCd because, in general, NFC of this forage consists largely of starch, and, according to the NRC (2001), the digestibility of sorghum starch is lower than that of other forage sources.

The TDN varied with the dry matter digestibility. Van Soest (1994) described that the conversion of DMd to energy equivalent units involves adjustments for the fat and ash contents. The ash correction can be larger of the two for ruminants because lipid content of feedstuffs is small and variable. The OMd also matched TDN ($r = 0.768$). In this study, ash did not alter either intake or digestibility. In addition, the low lipid content of the experimental diets led to a close relationship between TDN and CPd and between TDN and NFCd ($r = 0.790$ and $r = 0.791$ respectively).

4.4. Milk parameters

Cows fed corn and sorghum silages did not lose body weight. Despite the lower intake of sorghum silage than corn silage, energy needs for maintenance, milk production and pregnancy requirements apparently were met with these two diets. But when corn and sorghum silages were replaced by fresh sugarcane or sugarcane silage, cows lost weight and had decreased milk production. Notably, the sugarcane silage diet caused the greatest weight loss due to its low DMI and digestibility. Despite the lower intake of sugarcane silage than fresh sugarcane, milk yield did not differ between these two treatments. Possibly, cows fed sugarcane silage mobilized more body reserves.

Dias et al. (2001) replaced all the corn silage with sorghum silage for Holstein cows, and reported similar results. Despite great corn silage intake, cows had similar rates of milk production. However, when Costa et al. (2005), Magalhães et al. (2004) and Mendonça et al. (2004), substituted fresh

sugarcane for corn silage in diets for cows, they observed decreased DMI and milk yield that become more pronounced as fresh sugarcane replaced more of the dietary concentrate.

Among the milk components, normally fat is the component that varies most among diets. In general, milk fat content reflects the fermentation process in the rumen. Valadares Filho et al. (2000) when testing different concentrate levels for lactating cows, observed a reduction in milk fat content when cows were fed diets with more than 65% concentrate and ascribed this to high NFC levels that increased ruminal propionate and reduced the ruminal pH. However, Sancanari et al. (2001) observed an increase in milk fat content when they supplied rumen-protected amino acids, possibly because amino acids increased the plasma levels of non-esterified fatty acids for the mammary gland to use for milk fat synthesis. In this study, no significant variables were found related to milk fat content.

Similar effects were observed for other milk solids (Table 5). An increase in milk protein requires more microbial protein and thereby a greater supply of dietary NFC. This can increase in the supply of amino acids for the mammary gland for protein synthesis. In the case of lactose synthesis, intense gluconeogenesis is required to produce large amounts of glucose. The majority of amino acids absorbed are used in gluconeogenesis (Valadares Filho et al., 2000). However, the NFC level used in experimental diets of this study probably was not sufficient to alter milk solids, dry milk solids or non-fat dry milk solids.

4.5. In situ degradation kinetics

The dynamics of the DM and NDF ruminal degradation data is presented in Table 6. Fresh sugarcane had the highest DM soluble fraction (a) due to the high amount of carbohydrates present mainly as sucrose. High amount of carbohydrates increased effective degradation of this forage. The potentially degraded fraction of DM (b) and the disappearance rate of the DM (kd) were lower for fresh sugarcane than other forages, perhaps a consequence of the higher undegraded fraction of the NDF (I) and lower degradation rate for NDF that increases ruminal retention time and reduces intake of DM and NDF. Russell et al. (1992) described that a high fraction of indigestible carbohydrates, similar to that of fresh sugarcane, probably affects the availability of energy for fibrolytic bacteria, resulting in a slow rate of particle escape and a slow passage rate, thereby reducing ruminal turnover and microbial efficiency.

In contrast, sorghum silage (Table 6) had the lowest soluble fraction (a) among the forages, but that was compensated for by a higher potentially degraded fraction (b) than other forages. The effective degradability also was lower. This can explain the lower intake when compared to corn silage, due to ruminal fill, as well as the high iNDFI of this diet, and the lower pdNDF factor compared to corn silage. Sorghum silage had a lower disappearance rate for NDF (kd) compared to corn silage.

Sugarcane silage had a lower disappearance rate (kd) for DM than corn and sorghum silages (Table 6) and an even lower disappearance rate for NDF. This can explain its low consumption. Fernandes et al. (2003) described that the low degradation rate of the sugarcane fiber causes a large ruminal fill that limits DMI, and causes a limitation in production of animals with high nutritional requirement.

Corn silage had the highest disappearance rate (kd) for DM and NDF and the highest effective degradation of NDF (Table 6). This finding can explain the higher DMI and the higher NDF digestibility of this forage in comparison to others. The high degradation rate of NDF increases the possibility that undigested NDF can escape ruminal digestion.

4.6. Metabolic parameters

Plasma concentration of non-esterified fatty acids (NEFA) was highest for cows fed sugarcane silage (Table 7). This indicates that body reserves of adipose tissue were mobilized by these cows to maintain milk production (Table 5). According to Harrison et al. (1990), DMI and the NEFA level in the plasma are correlated negatively because the NEFA represent triglyceride mobilization from adipose tissue. Weight loss of high-producing cows in early lactation also reflects the mobilization of adipose and muscle tissues necessary to support milk production. In the case of this experiment, although the cows did not have a high milk yield, low DMI was probably compensated by increased body reserve mobilization to maintain milk production.

Nitrogen balance was greatest for cows fed corn and sorghum silage (Table 7), followed by fresh sugarcane, and finally sugarcane silage. This probably reflects differences in DMI and, consequently, the crude protein intake, which altered fecal nitrogen excretion and milk nitrogen secretion. Wright et al. (1998) reported that urine is the first route of nitrogen excretion when protein intake or losses of nitrogen from the rumen, intestines or mammary glands increase. In this study, no statistical differences in urine nitrogen were detected. Perhaps variation in the fecal and milk nitrogen contents reflected changes in nitrogen balance but did not result in such severe metabolic losses that N excretion increased. The milk nitrogen was highest for cows consuming corn silage, probably due to their high DMI and CPI and their higher milk yield.

Corn and sorghum silages resulted in positive nitrogen balances and higher milk production due to formulation of the diets; they did not cause a nitrogen deficiency for the cows. However, the negative nitrogen balance for fresh sugarcane and sugarcane silage was reflected in reduced milk yield, probably due to lower dry matter and protein intakes.

The highest concentration of nitrogen as urea in the urine, plasma and milk was found with cows fed sugarcane silage, probably due to increased excretion of urea by cows losing weight. This may reflect the greater mobilization of body reserves for cows fed this experimental diet.

Cows fed the corn silage-based diet excreted the highest amounts of total purines and microbial nitrogen in the rumen of all the treatments (Table 7). This probably reflects higher consumption of nutrients and a greater availability of substrates for fermentation. According to Van Soest (1994), production of microbial mass increases with consumption of digestible energy. Thus, an increased DMI increases passage rate and ruminal turnover. This favors removal of slowly fermented particles from the rumen and decreases time that microbes must spend at maintenance therefore removes more mature microorganisms. Nocek and Russell (1988)

reported that the growth of microorganisms and the end products of microbial metabolism are dependent on the carbohydrate supply. When ATP is available in the rumen, amino acids can be incorporated by microbes and used for protein synthesis. This fact can explain the increased level of microbial nitrogen production in the rumen of cows consuming corn silage.

Surprisingly, the microbial efficiency of the corn silage-based diet was not superior to that of other diets (Table 7). Cows consuming sugarcane silage had the highest microbial efficiency followed by fresh sugarcane; corn and sorghum silages that had the lowest efficiencies. Van Soest (1994) described that the efficiency optimization of microbial protein production during rumen fermentation is controlled by two main factors: the rate of fermentation of feed per unit of time and the rate of passage. Thus, the low intake of sugarcane silage and its low rates of degradation in the rumen increased the time for the degradation of the potentially degraded fractions, and resulting in a microbial nitrogen production equal to that of sorghum silage and fresh sugarcane. Despite the low TDN intake, microbial protein produced per kilogram of TDN consumed was high. When there is not any optimal level of ATP for sufficient microbial protein synthesis, amino acids are fermented as an energy source, resulting in increased microbial protein produced, even with the low TDN intake (Nocek and Russell, 1988).

5. Conclusions

Feeding F1 Holstein × Gir cows with a sugarcane silage-based diet resulted in a low DM intake, low digestibility of nutrients and high mobilization of body reserves. Tissue mobilization allowed milk production to be similar to that of cows fed fresh sugarcane. Further studies are needed to establish an optimum forage:concentrate ratio for the fresh sugarcane-based diets as well as the sugarcane silage-based diets for crossbred cows to optimize DMI. Corn silage and sorghum silage provided satisfactory cow performance, even at a very high forage:concentrate ratio. Intakes of these forages were sufficient to meet the nutritional requirements of the cows and to maintain body condition and metabolic parameters within the normal range.

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